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van Koppenhagen, Casper F.; de Groot, Sonja; Post, Marcel W. M.; van Asbeck, Floris W. A.; Spijkerman, Dorien; Faber, Willemijn X. M.; Lindeman, Eline; van der Woude, Lucas H. V.

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ORIGINAL ARTICLE

Patterns of Changes in Wheelchair Exercise Capacity After Spinal Cord Injury

Casper F. van Koppenhagen, MD,^{a,b} Sonja de Groot, PhD,^{c,d} Marcel W. Post, PhD,^{a,b} Trynke Hoekstra, PhD,^e Floris W. van Asbeck, MD, PhD,^b Helma Bongers, MD,^f Eline Lindeman, MD, PhD,^{a,b,†} Luc H. van der Woude, PhD^c

From the ^aDepartment of Rehabilitation Medicine and Rudolf Magnus Institute for Neuroscience, University Medical Center Utrecht, Utrecht; ^bRehabilitation centre De Hoogstraat Rehabilitation Utrecht, Utrecht; ^cUniversity of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, Groningen; ^dAmsterdam Rehabilitation Research Center | Reade, Amsterdam; ^eDepartment of Health Sciences, Free University of Amsterdam, Amsterdam; ^fAdelante Rehabilitation, Hoensbroek, The Netherlands.

Abstract

Objectives: (1) To identify different patterns of changes in wheelchair exercise capacity in the period between the start of active spinal cord injury (SCI) rehabilitation and 5 years after discharge; (2) to examine the pattern determinants of the change in wheelchair exercise capacity.

Design: Prospective cohort study. Measurements were recorded at the start of active inpatient rehabilitation, 3 months after the start, at discharge of inpatient rehabilitation, 1 year after discharge, and 5 years after discharge.

Setting: Eight rehabilitation centers.

Participants: Persons with SCI (N=130; age range, 18–65y), who were wheelchair-dependent, at least for long distances.

Interventions: Not applicable.

Main Outcome Measure: Wheelchair exercise capacity: peak power output (W).

Results: We found 4 different patterns of the change of peak power output (mean \pm SD): (1) a pattern with high and progressive scores (33% of total study group): high progressive scores (start of rehabilitation: 49 ± 15 W to 5 years after discharge: 77 ± 17.2 W); (2) a pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation (12%): progressive scores during inpatient rehabilitation with deteriorating scores after discharge (start of rehabilitation: 29 ± 8.7 W, to discharge: 60 ± 8.4 W, to 5 years after discharge: 39 ± 13.1 W); (3) a pattern with low and only slightly progressive scores (52%): low progressive scores (start of rehabilitation: 20 ± 10.1 W to 5 years after discharge: 31 ± 15.9 W); and (4) a pattern with low scores during inpatient rehabilitation and a sharp rise after discharge (3%): low inpatient scores with strong progressive scores after discharge (start of rehabilitation: 29 ± 15.5 W to 5 years after discharge: 82 ± 10.6 W). A logistic regression of factors that may distinguish between patterns with high and progressive scores and patterns with low and only slightly progressive scores revealed that older age, being a woman, having a tetraplegic lesion, and low functional status were associated with patterns with low and only slightly progressive scores. The pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation showed more neuropathic pain and lower sports participation than patterns with high and progressive scores.

Conclusions: For the vast majority of patients, wheelchair exercise capacity after SCI shows a positive trend and can be described in distinct patterns that are dependent on personal, lesion, and functional characteristics.

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A spinal cord injury (SCI) is a devastating medical condition that highly affects the exercise capacity of the persons involved as a result of muscle weakness, loss of autonomic control below the

level of injury, and subsequent changes in metabolic and vascular functions.¹⁻⁵ Most people with an SCI have a sedentary lifestyle, and the maintenance of an adequate exercise capacity is hindered by medical problems, social barriers, low activity levels, and low sport participation.^{1,3,4,6-8} This potentially leads to a debilitating cycle of exercise capacity and exposes these individuals to an increased risk of developing medical conditions, such as metabolic

[†] Deceased.

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syndrome and cardiovascular disease, which is the leading cause of death in persons with an SCI.⁹

Longitudinal research on the change in exercise capacity is scarce. We previously have shown the recovery of exercise capacity up to 1 year after discharge from inpatient rehabilitation¹⁰ and subsequent stabilization up to 5 years after discharge.¹¹ The most previous research on exercise capacity in SCI had a cross-sectional design, and their results were influenced by an overrepresentation of active and young patients with paraplegia.¹²⁻¹⁴ Variable-centered statistical approaches revealed that age, sex, and lesion level and completeness to be longitudinal,^{10,11} and that cross-sectional¹²⁻¹⁴ was related to exercise capacity. Other determinants of exercise capacity were secondary impairments, pain, and activity levels.¹⁵⁻¹⁷ However, clinical observations suggest a certain amount of heterogeneity in the change of exercise capacity after SCI. A person-centered statistical method known as latent class growth mixture modeling (LCGMM)¹⁸⁻²⁰ is an appropriate method to unravel this heterogeneity, which may help us understand how individuals differ in their physical adaptation to an SCI. Follow-up rehabilitation care of persons with an SCI may be improved by identifying the different patterns and characteristics of people at risk for persistently low levels or the deterioration of exercise capacity.

The aims of the present study are (1) to identify different patterns of the change of wheelchair exercise capacity in the period between the start of active SCI rehabilitation and 5 years after discharge and (2) to examine the determinants of these different patterns of wheelchair exercise capacity. We hypothesized that different wheelchair exercise capacity patterns would be identified and that older age, being a woman, tetraplegia, a complete lesion, a nontraumatic lesion, a long rehabilitation period, poor functional independence, low activity level, and suffering from pain or other secondary impairments would be identified as determinants of a low or deteriorating pattern of wheelchair exercise capacity.

Methods

Participants

Eight rehabilitation centers specializing in SCIs participated in the project. The participants were eligible to join the project if they had an acute SCI, were between 18 and 65 years of age, were classified as grades A to D on the ASIA Impairment Scale (AIS), and were expected to remain wheelchair-dependent for at least long distances. The exclusion criteria were SCI because of malignancies, progressive disease, known cardiovascular disease, or psychiatric problems, and insufficient command of the Dutch language to

understand the goal of the study and the testing methods. The Medical Ethics Committee of the Stichting Revalidatie Limburg/Institute for Rehabilitation Research in Hoensbroek and all local medical ethics committees approved the research protocol in 1999. The Medical Ethics Committee of the University Medical Center Utrecht approved the sequel research protocol in 2006. All participants gave written informed consent.²¹

Procedure

Measurements were performed at the start of active inpatient rehabilitation, defined as the day that a person could sit for 3 to 4 hours accumulatively, 3 months after start of active inpatient rehabilitation, at discharge from inpatient rehabilitation, 1 year after discharge, and 5 years after discharge. These 5 measurements included a medical history and physical examination by a rehabilitation physician, an oral interview with a trained research assistant, a self-reported questionnaire, and a peak wheelchair exercise test. For persons with a short inpatient rehabilitation period, the 3-months measurement was replaced with the measurement at discharge.

Instruments

Peak power output and peak oxygen consumption

Wheelchair exercise capacity, expressed as peak power output (PO_{peak} [W]) and peak oxygen consumption (VO_{2peak} [L/min]), was determined in a peak wheelchair exercise test on a motor-driven treadmill. The testing protocol and equipment have previously been described.^{10,22,23,a,b,c} At every occasion before the maximal exercise test for each subject, the wheelchair drag force (N) for the wheelchair-user combination on the treadmill was recorded in a drag test. The participants performed 2 blocks of submaximal exercise of 3 minutes each, separated by a 2-minute rest. After 2 minutes of rest, the peak exercise test started at the same constant velocity, and the inclination was increased .36° every minute. The test was terminated when the subject was exhausted or could no longer keep pace with the speed of the treadmill. The individual testing protocol was identical for each of the testing occasions. Peak VO_2 was defined as the highest value of oxygen consumption recorded during a 30-second period. Peak PO was defined as the power output at the highest inclination that the subject could maintain for at least 30 seconds.

Personal and lesion characteristics

Demographic characteristics

The demographic characteristics collected at the first test were age, sex, body mass, and height. Body mass (kg) was measured by the trained research assistant with each subsequent test. Body mass index (BMI) was calculated in $kg \cdot m^{-2}$.

Lesion characteristics

Lesion characteristics were assessed according to the International Standards for Neurological Classification of Spinal Cord Injury.²⁴ AIS grades A and B were considered motor complete, and grades C and D were considered motor incomplete. Neurologic lesion level was defined as the highest motor level. Neurologic levels below T1 were defined as paraplegia, and neurologic lesion levels at or above T1 were defined as tetraplegia. The cause of injury was

List of abbreviations:

AIS	ASIA Impairment Scale
BIC	Bayesian information criterion
BLRT	bootstrapped likelihood ratio test
BMI	body mass index
LCGMM	latent class growth mixture modeling
MET	metabolic equivalent of task
PASIPD	Physical Activity Scale for Individuals with Physical Disabilities
PO_{peak}	peak power output
SCI	spinal cord injury
VO_{2peak}	peak oxygen consumption

separated by traumatic versus nontraumatic causes. The length of rehabilitation was defined as the number of days from admission to discharge from inpatient rehabilitation.

Functional independence

Functional independence was measured with the motor score of the FIM, which consisted of 13 items regarding self-care, mobility, transfers, and toileting.²⁵ The responses ranged on a 7-point scale from 1 (fully dependent) to 7 (fully independent). A total score was calculated and used in the analyses.

Secondary impairments were grouped into the 3 following categories.

Musculoskeletal pain

Thirteen locations were evaluated in terms of musculoskeletal pain (bilateral fingers/wrist, elbow, shoulder, hip, knee, ankle/foot, and back/neck). All of the locations were scored as absent (0) or present (1) during the last 12 months. A total musculoskeletal pain score was computed as the sum of all items (range, 0–13).

Neuropathic pain

The evaluation was composed of 1 item about nonmusculoskeletal pain and 8 other abnormal sensations, such as numbness, tingling, burning, phantom, hot or cold feelings, itching, and dull feelings. All of the items were scored as absent (0) or present (1) during the last 12 months. A total neuropathic pain score was calculated as the sum score of all items (range, 0–9).

Other secondary impairments

Seven items, including pressure ulcers, urinary tract infections, pulmonary infections, neurogenic heterotopic ossification, edema, hypotension, and autonomic dysreflexia, were scored as absent (0) or present (1) during the last 12 months. A total score was computed (range, 0–7).

Physical Activity Scale for Individuals with Physical Disabilities

Information about the level of physical activity (leisure, household, and occupational activity) was collected using the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD).²⁶ The PASIPD was developed to assess the self-reported physical activity level of individuals with a disability, expressed in metabolic equivalent of task (MET [hour/day]) (maximum score is 182.3 MET hour/day). One MET is defined as the amount of oxygen required per minute under quiet resting conditions. The PASIPD was evaluated in people with disabilities and in people with SCI for construct validity, reliability, and criterion validity.^{26–28} The PASIPD showed a moderate relation with activity parameters and a weak to moderate relation with fitness measures in people with SCI; the reported Cronbach alpha was .63.²⁸

The Utrecht Activity List for sport was used to assess the time spent on sports in hours per week.²⁹ This questionnaire is a Dutch adaptation of part of the Craig Handicap Assessment Rating Technique.³⁰

Statistics

The descriptive statistics (means \pm SDs) were calculated with SPSS version 18.0^d for all of the test occasions.

Only the participants who performed at least 2 out of the 5 wheelchair exercise tests were included in the analyses. Two outliers were detected using scatter plots and multivariate analysis, resulting in exclusion from the dataset and leading to a study group of 130 persons. We used chi-square tests and *t* tests to compare data between the participants and the loss to follow-up group at the start of active rehabilitation.

Latent class growth mixture modeling

The patterns of the changes of the dependent variable exercise capacity (PO_{peak} and VO_{2peak}) were determined by fitting an LCGMM to the data¹⁹ using the Mplus 6.1 software program.^{31,e} The LCGMM is a contemporary longitudinal technique based on structural equation modeling, which incorporates both continuous and categorical latent (unobserved) variables. The aim is to capture heterogeneity in the change of exercise capacity within an optimal number of subgroups, each with a unique pattern. Each subgroup might have its own regression coefficients when its pattern of changes in wheelchair capacity is expressed as a function of selected independent variables. The optimal model is one where individuals within a subgroup are the most similar to each other and the most different to individuals in other subgroups. To determine the optimal number of patterns, a forward approach was started with a model with 1 developmental pattern, assuming that all individuals in the study had the same change of PO_{peak} and VO_{2peak} . A pattern was subsequently added each time, and the model fit was assessed. The Bayesian information criterion (BIC) and the bootstrapped likelihood ratio test (BLRT) were used to determine the optimal number of patterns. Lower values of the BIC and a significant *P* value of the BLRT indicate a better model fit.¹⁹ The participants were assigned to the pattern to which they had the highest probability of belonging by using posterior probabilities.

We performed logistic regression analyses between the distinctive pairs of patterns to determine which variables could discriminate. The dependent variable in the logistic regression analyses was the dichotomous group membership. The independent variables were age, sex, BMI, level of lesion, completeness of lesion, cause of lesion, length of rehabilitation, FIM, secondary impairments total score, neuropathic pain total score, musculoskeletal pain, and activity levels.

The bivariate logistic regression analyses were first performed to select the independent variables for the multivariate models by using the selection criteria of $P < 0.1$. Second, a backward elimination method was used for the multivariate model, leading to a final model composed of only significant predictors ($P < .05$). SPSS version 18.0 was used for the regression analyses.

Results

Participants' characteristics

At the start of active rehabilitation, 225 people with SCI were included in the cohort study. One hundred and nine of 225 persons participated in the peak exercise test at the start of active inpatient rehabilitation, 95 of 155 at 3 months after start of active inpatient rehabilitation, 137 of 198 at discharge, 91 of 156 at 1 year after discharge from inpatient rehabilitation, and 73 of 149 at 5 years after discharge from inpatient rehabilitation. The 132 participants who performed at least 2 peak exercise tests were included in the analyses. Two outliers were detected using scatter plots and

Table 1 Participant and lesion characteristics for participants and nonparticipants (EXCLUDED) and between distinct patterns of changes in wheelchair exercise capacity (PO_{peak}) (N=130)

Characteristics	Participants (N=130)	EXCLUDED (n=95)	HIGH-PRO (n=43)	DETER (n=15)	LOW-PRO (n=69)	LOW-RISE (n=3)
Male sex	74.6	74.2	95.3	93.3	56.5	100.0
Age at start (y)	38.7±13.7	44.1±13.9*	36.4±13.0	32.9±10.4	41.5±14.5	37.8±5.8
Body mass (kg) at start	72.6±14.5	72.7±13.6	76.0±13.0	74.8±14.3	70.3±15.3	67.3±15.3
Paraplegic lesion	72.1	42.3*	97.7	93.3	52.2	100.0
Complete lesion	68.5	69.3	69.8	66.7	68.1	100.0
Traumatic cause of injury	76.0	69.0	81.4	93.3	68.1	100.0
Length of rehabilitation (d)	248.1±132.3	265.1±150.8	203.8±92.8	240.2±67.6	282.3±152.1	118.3±10.6

NOTES. Values are %, mean ± SD, or as otherwise indicated. Missing data are ignored.

Abbreviations: DETER, pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation; EXCLUDED, loss to follow-up group; HIGH-PRO, pattern with high progressive scores; LOW-PRO, pattern with low and only slightly progressive scores; LOW-RISE, pattern with low scores during inpatient rehabilitation and a sharp rise after discharge; start, start of active inpatient rehabilitation.

* Significant difference with $P < .05$ between participants and EXCLUDED, tested with chi-square and t tests.

a multivariate analysis, resulting in their exclusion from the dataset and leading to a participants group of 130 persons (table 1).

A comparison of personal and lesion characteristics between participants (N=130) and loss to follow-up groups (see table 1, column EXCLUDED, n=95) showed that the loss to follow-up group had a higher lesion level and were of older age.

Exercise capacity patterns

A model with 4 wheelchair exercise capacity patterns for PO_{peak} best represented the data, that is, having the lowest BIC number and a significant P value of BLRT (table 2).

The first pattern (pattern with high progressive scores) consisted of 43 participants with initially high levels of exercise capacity and strong increments during their inpatient rehabilitation and the first year after discharge, stabilizing between 1 and 5 years after discharge (fig 1). The second pattern (pattern of improvement during inpatient rehabilitation and deterioration after discharge) contained 15 participants showing improvement in exercise capacity during inpatient rehabilitation but deterioration after discharge. The third pattern (pattern with low and only slightly progressive scores) (n=69) showed low levels of exercise capacity at the start of active inpatient rehabilitation and a relatively strong improvement over time. The fourth pattern (pattern with low scores during inpatient rehabilitation and a sharp rise after discharge) consisted of only 3 people, with low levels during inpatient rehabilitation and a relatively sharp performance increase from discharge up to 5 years after discharge.

Table 2 Model fit indices for the selection of the number of patterns of changes for PO_{peak}

Number of Patterns	BIC	BLRT (P)	Average Posterior Probabilities	Number of Participants (N=130)
K=1	3683.078	NA	1.000	130
K=2	3671.695	<.001	0.955	59/71
K=3	3673.948	.013	0.963	3/68/59
K=4	3670.725	<.001	0.924	3/43/69/15
K=5	3682.838	.667	0.916	15/65/3/4/43

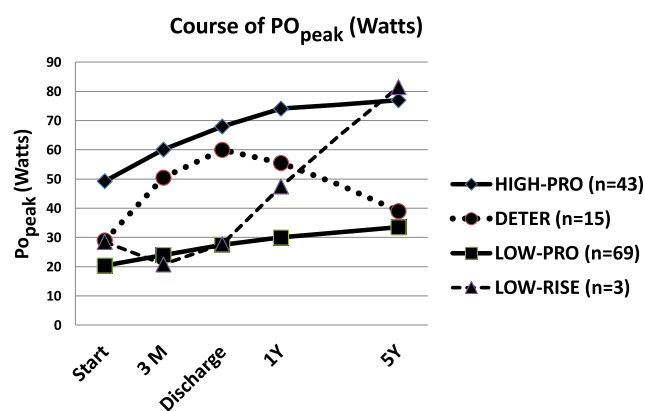
Abbreviation: NA, not applicable.

Determinants of pattern membership

All of the characteristics per PO_{peak} pattern are displayed in tables 1 and 3 (columns HIGH-PRO, DETER, LOW-PRO, and LOW-RISE). The pattern with low scores during inpatient rehabilitation and a sharp rise after discharge contained 3 men with complete paraplegic lesions who had a relatively short length of rehabilitation, low functional status, and low wheelchair exercise capacity at discharge. The pattern with low scores during inpatient rehabilitation and a sharp rise after discharge (n=3) was not taken into account in the remaining analyses of the determinants because of the small group size.

Pattern with high progressive scores versus pattern with low and only slightly progressive scores

Logistic regression analyses were performed between the pattern with high progressive scores and the pattern with low and only slightly progressive scores and between the pattern with high progressive scores and pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation. Compared with people in the pattern with low and only slightly progressive scores, people in the pattern with high

**Fig 1** Distinct patterns of the change of PO_{peak} (W) up to 5 years after discharge of inpatient rehabilitation.

progressive scores were commonly young men with paraplegic lesions, a short length of rehabilitation, high functional status, and less musculoskeletal and neuropathic pain (bivariate analyses) (table 4).

A multivariate analysis detected 4 determinants of high power output in the wheelchair exercise test. These determinants were the following: the odds of being a member of the pattern with high progressive scores was .02 for women, .03 for persons with tetraplegia, .93 for older age, and 1.09 for higher functional status (table 5). Taken together, these results explain a large proportion of the variance (Nagelkerke pseudo- $R^2 = .70$). The presence of neuropathic pain approached significance ($P = .057$).

Pattern with high progressive scores versus pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation

The pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation consisted mostly of men of a young age and with a paraplegic lesion of traumatic origin (see table 1). No differences were found with regards to the personal and lesion characteristics between the high progressive scores and improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation patterns (see table 4). Subjects in the pattern with high progressive scores showed less

neuropathic pain and scored higher in the Utrecht Activity List for sports than the subjects in the pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation (see table 4). A multivariate analysis confirmed the determinants of deteriorating power output in the wheelchair exercise test over time, which were the following: the odds for being a member of the pattern with high progressive scores was 1.48 for people with high sports participation and .63 for people with high neuropathic pain (see table 5), together explaining a small proportion of the variance (Nagelkerke pseudo- $R^2 = .394$).

Discussion

Our hypothesis that the exercise capacity in our cohort of Dutch patients with SCI follows distinct patterns from the start of active rehabilitation up to 5 years after discharge was supported. We found 4 different patterns. For the vast majority (pattern with low and only slightly progressive scores, pattern with low scores during inpatient rehabilitation and a sharp rise after discharge, and pattern with high progressive scores; total = 88%) of the study population, the exercise capacity improved up to 5 years after discharge. A minority (pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation, 12%) showed a clear deteriorating trend after discharge. The second hypothesis was only partially confirmed: older age, being a woman, tetraplegic lesion, and low functional status were associated with low progressive pattern of PO_{peak} . These results underlined the findings of variable-centered studies.¹⁰⁻¹⁴ In accordance with the literature, we could confirm an association between the pain and activity level for patients with deterioration of wheelchair exercise capacity.¹³⁻¹⁷

Compared with the variable-centered analyses on the change^{10,11} or status¹²⁻¹⁴ of exercise capacity, the subject-centered LCGMM revealed different recovery patterns and identified the characteristics of patients with low or deteriorating levels.

We made a choice between PO_{peak} and VO_{2peak} with respect to the length of the article and the high correlation between PO_{peak} and VO_{2peak} . Peak VO_2 is a general fitness measure at the level of body function. PO_{peak} in a handrim wheelchair exercise is more of a functional measure of wheelchair propulsion capacity at the activity level and is determined not only by oxygen consumption but also by gross mechanical efficiency (skill technique), muscle force capacity, and anaerobic power production. We chose the most functional measure (PO_{peak}) for further analyses.

The pattern with high progressive scores showed high progressive levels of exercise capacity and a progression of 47% over time, which might be because of the high amount of participants who were men with paraplegia in this pattern class (see table 1) and the resulting high functional independence¹⁰ and the relatively short length of rehabilitation.³²

The pattern with low and only slightly progressive scores almost contained all of the subjects with tetraplegia (see table 1) from the whole study group. The subjects with tetraplegia have few available functional muscles and less sympathetic control of the cardiovascular system to cope with exercise demands, resulting in reduced oxygen consumption, power output, and improvement potential.^{2,33} This partially explains the relatively low wheelchair exercise capacities in this pattern. The pattern with low and only slightly progressive scores was also mostly composed of women (see table 1), who generally have lower oxygen consumption because of their lower mean body masses.¹⁵

Table 3 Variables related to wheelchair exercise capacity (PO_{peak}) (n = 127) of persons with SCI between distinct patterns of changes

Characteristics	HIGH-PRO (n = 43)	DETER (n = 15)	LOW-PRO (n = 69)
BMI			
Start	23.1±3.2	22.7±3.3	22.7±4.1
5Y	25.4±4.0	25.2±4.1	25.4±5.5
FIM (13–91)			
Start	54.3±16.7	47.6±13.5	42.2±18.2
5Y	77.3±6.9	76.8±7.9	59.4±21.0
Secondary impairments			
Start	1.3±1.0	1.4±1.1	1.4±1.3
5Y	1.7±1.4	1.3±0.8	1.3±0.8
Neuropathic pain			
Start	2.6±1.8	3.6±1.6	3.1±1.7
5Y	2.4±1.6	4.1±2.6	3.3±2.1
Musculoskeletal pain			
Start	1.5±1.5	2.0±2.0	2.2±2.2
5Y	2.0±2.4	2.9±2.4	3.3±3.1
Participation			
1Y	23.5±15.8	18.5±20.5	16.0±18.6
5Y	24.8±18.0	18.8±15.4	18.1±18.6
Sports participation			
1Y	3.5±4.5	1.6±2.1	1.9±3.7
5Y	4.7±5.4	1.0±1.7	3.8±6.6

NOTE. Missing data are ignored. Data are mean ± SD.

Abbreviations: DETER, pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation; 5Y, 5 years after discharge from inpatient rehabilitation; HIGH-PRO, pattern with high progressive scores; LOW-PRO, pattern with low and only slightly progressive scores; 1Y, 1 year after discharge from inpatient rehabilitation; start, start of active inpatient rehabilitation.

Table 4 Bivariatic logistic regression analyses to distinguish between HIGH-PRO (n=43) and LOW-PRO (n=69) patterns of changes and between HIGH-PRO (n=43) and DETER (n=15) patterns of changes in wheelchair exercise capacity (PO_{peak}) in SCI

Variables	HIGH-PRO vs LOW-PRO (n=81)		HIGH-PRO vs DETER (n=58)	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age (higher)	0.97	0.95–1.00*	1.03	0.97–1.10
Sex (female)	0.06	0.01–0.28*	0.63	0.05–7.57
Lesion level (tetraplegic)	0.03	0.04–0.21*	3.00	0.48–3.00
Complete lesion	1.38	0.60–3.16	1.26	0.79–3.45
Cause of lesion (traumatic)	1.99	0.70–5.59	1.16	0.82–1.63
Length of rehabilitation (longer)	0.99	0.99–0.99*	0.99	0.98–1.00
BMI start (higher)	1.02	0.92–1.13	1.09	0.85–1.21
BMI 5Y (higher)	1.00	0.91–1.10	1.01	0.96–1.10
FIM start (higher)	1.04	1.01–1.10*	1.02	0.96–1.10
FIM 5Y (higher)	1.09	1.04–1.15*	0.99	0.88–1.13
Secondary impairments (more)	0.84	0.60–1.17	1.21	0.64–2.31
Musculoskeletal pain (more)	0.83	0.69–0.99	0.97	0.70–1.37
Neuropathic pain (more)	0.74	0.58–0.94	0.69	0.49–0.99*
Participation (higher)	1.02	0.99–1.05	1.02	0.95–1.09
Sports participation (higher)	0.98	0.91–1.05	1.45	1.10–2.06*

Abbreviations: CI, confidence interval; DETER, pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation; 5Y, 5 years after discharge from inpatient rehabilitation; HIGH-PRO, pattern with high progressive scores; LOW-PRO, pattern with low and only slightly progressive scores; sports participation, the Utrecht Activity List for sports; start, start of active inpatient rehabilitation.

* Significance set at $P < 0.1$. An odds ratio < 1 describes lower probability to be in the HIGH-PRO group.

Nevertheless, the pattern with low and only slightly progressive scores showed a progression over 50% (20.1–31.2W) for PO_{peak} from start of active rehabilitation up to 5 years after discharge from inpatient rehabilitation (see fig 1). This improvement might protect people with SCI from musculoskeletal overload injuries in their daily life activities³⁴ and might promote participation in work, sport, and other leisure activities.³⁵ When compared with PO_{peak} , the lower improvement in VO_{2peak} (25%, figures not presented) indicates that the simultaneous improvements of anaerobic exercise capacity and wheelchair skills and technique, which result in a better wheelchair propulsion efficiency,¹⁰ do take place in the course of time.

The pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation class consisted of subjects that should have been able to keep their wheelchair exercise capacity at least stable, because it had the youngest participants and mostly consisted of men with complete paraplegia.¹⁵ The scores of the independent variables BMI, functional status, secondary impairments, and musculoskeletal pain of the pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation were almost identical to those of the pattern with high progressive scores. According to these characteristics, these subjects should have been clustered in the pattern with high progressive scores class. Because of the

Table 5 Outcome of backward multivariate logistic regression analyses to distinguish between HIGH-PRO (n=34) and LOW-PRO (n=47) patterns of changes and between HIGH-PRO (n=34) and DETER (n=15) patterns of changes in wheelchair exercise capacity (PO_{peak}) in SCI at 5 years after discharge of inpatient rehabilitation

Variables	HIGH-PRO vs LOW-PRO (n=81)		HIGH-PRO vs DETER (n=58)	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age (higher)	0.930	0.87–1.00*	NE	
Sex (female)	0.020	0.00–0.02*	NE	
Lesion level (tetraplegic)	0.030	0.00–0.39*	NE	
FIM 5Y (higher)	1.090	1.00–1.18*	NE	
Neuropathic pain 5Y (more)	NE	NE	0.630	0.42–0.93*
Length of rehabilitation	NS	NS	NE	
Sports participation (higher)	NE	NE	1.48	0.95–2.30*
Nagelkerke pseudo- R^2	0.708		0.394	
Predicted percentage correct	83.300		77.800	

NOTE. An odds ratio < 1 describes lower probability to be in the HIGH-PRO group.

Abbreviations: CI, confidence interval; DETER, pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation; 5Y, 5 years after discharge from inpatient rehabilitation; HIGH-PRO, pattern with high progressive scores; LOW-PRO, pattern with low and only slightly progressive scores; NE, not entered; NS, not significant.

* Significance set at $P < .05$.

small group size of the pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation group ($n=15$), we were cautious with conclusions from the comparative analyses between the improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation and high progressive scores patterns. Nevertheless, the logistic regression analyses revealed that the pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation showed more neuropathic pain and was less active in sports than the pattern with high progressive scores (see table 5); this is a possible explanation for the deterioration of exercise capacity after discharge that is caused by a debilitating cycle of pain-inactivity-low exercise capacity with long-term health consequences.^{16,17}

Contrary to the literature,^{13,14,16} sports participation was not a distinctive determinant for PO_{peak} between the pattern with high progressive scores and the pattern with low and only slightly progressive scores, which might have been caused by the relatively high sports participation in both patterns (4.6 and $3.8 \text{ hr} \cdot \text{wk}^{-1}$, respectively) (see table 4). Our activity level measures might have been overestimated because of the loss to follow-up of the older subjects with more severe lesions, who are prone to have lower activity levels.

The pattern with low scores during inpatient rehabilitation and a sharp rise after discharge class had a relatively short length of rehabilitation, low functional status, and low wheelchair exercise capacity at discharge. In view of the remarkable recovery after discharge, outpatient rehabilitation seems to have been sufficient for these persons.

Study limitations and implications

The relatively high dropout of subjects with tetraplegia and older age, who are prone to have lower physical fitness, might have resulted in an overestimation of the exercise capacity after SCI. However, the LCGMM allows the number of observations per person to vary, and therefore repeated measures and cases with missing values can be included in these analyses.

The small group size of the pattern with low scores during inpatient rehabilitation and a sharp rise after discharge and pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation forced us to interpret our results with caution. We realized that our participants group ($N=130$) was a selection, because we lost a substantial part (loss to follow-up group, $n=95$) of the original study group ($n=225$). This loss to follow-up group, which consisted of subjects with older age and more severe lesions, might have had more secondary impairments, more pain, and lower activity levels; however, this is only speculation and needs to be studied in detail, which is beyond the scope of this article.

The distinct patterns give professionals some insight into how people differ in their physical adaptation to SCI up to 5 years after discharge. Monitoring wheelchair exercise capacity in SCI follow-up care might help to identify persons at risk for a debilitating cycle of exercise capacity with long-term health consequences.

Conclusions

We identified 4 different patterns of change in wheelchair exercise capacity after SCI for up to 5 years after discharge, which

expressed a positive trend for the vast majority (88%) of subjects. A minority (12%) showed a clear deteriorating trend. Older age, being a woman, tetraplegia, and low functional status were associated with a low progressive pattern. The identified pattern with deteriorating wheelchair exercise capacity consisted of men with paraplegia, mostly from traumatic causes, with relatively high neuropathic pain levels and low sports activity levels.

Suppliers

- Jaeger Toennies; Nikkelstr 2, 4823 AB Breda, The Netherlands.
- Treadmill Giant; Bonte BV, Rechterland 25, 8024 AH, Zwolle, The Netherlands.
- Polar Electro Finland Oy, Professorintie 5, FIN-90440 Kempele, Finland.
- SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
- Muthén and Muthén, 3463 Stoner Ave, Los Angeles, CA 90066.

Keywords

Cohort studies; Longitudinal studies; Physical fitness; Rehabilitation; Spinal cord injuries

Corresponding author

Casper F. van Koppenhagen, MD, De Hoogstraat Rehabilitation Utrecht, PO Box 85238, 3583 TM Utrecht, The Netherlands.
E-mail address: c.v.koppenhagen@dehoogstraat.nl.

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